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**Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals**

**Sub-Committee of Experts on the Transport of Dangerous Goods**

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Item 2 (e) of the provisional agenda
**Explosives and related matters: miscellaneous**

# Determination of friction sensitiveness using the Allegany Ballistics Laboratory (ABL) friction machine

**Transmitted by the expert from the United States of America**[1]

## Introduction

1. Sensitiveness of a substance to friction stimuli must be determined to ensure the safety of people and protection of property during shipment.

2. The ABL friction machine was included in the original Manual of Tests and Criteria as Series 3 (b) (iii) but was removed in the second revised edition (most likely due to the extensive trials specified in the original test procedure). This proposal is to reinstate the ABL friction machine, widely used in United States of America Government and international laboratories, as the Series 3 (b) (iii) test with an adapted test procedure that is consistent with the level of testing required by the other Series 3 (b) test options.

3. The ABL friction machine is a device that determines the friction sensitivity of a solid, semisolid, or powder substance using a sample of approximately 30 mg. It consists of an anvil upon which the sample is placed, a non-rotating wheel that is statically loaded to apply a predetermined load to the sample, and a pendulum that strikes the anvil propelling it to a known velocity over a travel distance of approximately 2.54 cm (1 in.). The amount of energy imparted to the sample is controlled by pressure on the wheel and the drop angle of the pendulum creating anvil velocity. Initiation is observed by an audible report or production of smoke, fire, charring or visible light.

[1] In accordance with the programme of work of the Sub-Committee for 2013-2014 approved by the Committee at its sixth session (refer to ST/SG/AC.10/C.3/84, para. 86 and ST/SG/AC.10/40, para. 14).

## Discussion

4. Several aspects of the ABL friction machine are advantageous for re-instatement into the Manual of Tests and Criteria:

(a) The ABL friction machine has a well-documented design that has been refined and standardized over 40 years; the current design also implements features to improve the quality and repeatability of the sensitivity data.

(b) The ABL friction machine was an original test method included in the Manual of Tests and Criteria under Test Series 3 (b) (iii).

(i) The test method was removed in the second revised edition most likely due to the extensive trials required per the prescribed test method which was more than the screen levels required of the other Series 3 (b) test options. The proposed method, based on test results and described below, provides a test procedure where the ABL friction machine can be used at a screening level, consistent to the level of testing required by the other Series 3 (b) test methods.

(ii) A place holder for the Series 3 (b) (iii) ABL friction machine test still remains in the current Manual.

(c) Despite the absence of the ABL friction machine test from the UN Manual of Tests and Criteria since the second revised edition, the ABL friction machine has been extensively used by many United States of America and international laboratories to characterize friction sensitivity of substances. Some of the laboratories include the following:

(i) Dugway Proving Grounds

(ii) Edwards Air Force Base (United States of America Air Force)

(iii) Los Alamos National Laboratory

(iv) Naval Air Warfare Center – China Lake (United States of America Navy)

(v) Naval Surface Warfare Center – Indian Head (United States of America Navy)

(vi) Air Force Research Laboratory – Tyndall Air Force Base (United States of America Air Force)

(vii) Federal Bureau of Investigation (FBI) / Rocky Mountain Scientific Laboratory

(viii) United States of America Department of Homeland Security (DHS) – Transportation Security Lab

(ix) Allegany Ballistics Laboratory (United States of America Navy)

(x) Lake City Army Ammunition Plant (United States of America Army)

(xi) Radford Army Ammunition Plant (United States of America Army)

(xii) Australian Department of Defence / Thales Group

(xiii) Japan Cariit Company

(d) The ABL friction machine is a preferred and recommended friction test for ammunition and explosives (AE) hazard classification by the United States of America Department of Defense (DoD).[2]

(e) The requirement to compare results to the friction sensitiveness of a reference sample of dry pentaerythritol tetranitrate (PETN) has been replaced by a single test level similar to the other Series 3 (b) test methods. Substances with a "+" test result, according to the proposed test criteria, are more sensitive than dry PETN.

(f) Using the proposed test procedure, the ABL friction machine can produce data at a rate similar to other tests currently used to determine friction sensitivity. The number of required trials has been significantly reduced from approximately 40 trials, for determination of the Threshold Initiation Level (TIL), to six trials, for determining if the material is too dangerous for transport (screening test).

(g) The ABL utilizes a single frictional pass across the substance (rather than a forward and backward pass) to ensure the substance is not modified by the test and is tested in the form in which it will be transported.

(h) The contact surfaces between the wheel and anvil are required to have a specific surface finish or surface roughness. The contact surfaces are designed to be refurbished and reused, in accordance with a standardized procedure. The frictional surfaces are made from material (MGR A8 Tool Steel) that is credibly found in transportation scenarios. This configuration yields a controlled and repeatable friction stimulus.

(i) The critical aspects of the ABL friction machine have been standardized via the Explosives Testing Users' Group (ETUG) including machine operation, calibration, and sample preparation procedures, along with defined reaction types. The ETUG is an international group of explosives testing experts with a charter to systematically minimize the variability associated with energetic materials testing to enable consistent/repeatable test data and interpretation of test results.

(j) Collecting friction sensitivity results with the ABL friction machine allows for broader use of the data to determine the safety of people and protection of property during all stages of transport, handling and use of the material. The ABL friction machine has been used by multiple engineering firms and national laboratories to express the friction results in calibrated engineering units based on empirical data ($N/m^2$ at a given velocity) that take into account the friction area and any energy losses. Data expressed in terms of engineering units is compared to the in-process value for a given process to determine risk.

## Proposal

5. It is proposed to include the ABL friction machine in the Test Series 3 (b) friction sensitivity options titled Test Series 3 (b) (iii), as follows:

"13.5.4 Test 3 (b) (iii): ABL friction machine test

13.5.4.1 *Introduction*

This test is used to measure the sensitiveness of the substance to friction stimuli and to determine if the substance is too dangerous to transport in the form tested. The

[2] See TB 700-2 (NAVSEAINST 8020.8C, TO 11A-1-47), Joint Technical Bulletin, Department of Defense Ammunition and Explosives Hazard Classification Procedures

test substance is subjected to a vertical compression force under a non-rotating wheel, while the substance is moved in a horizontal direction on a sliding anvil. It is applicable to solid, semisolid, and powder substances.

13.5.4.2 *Apparatus and materials*

13.5.4.2.1 The following apparatus and materials are required:

(a) A mechanism capable of applying a force hydraulically through a non-rotating steel wheel to a sample placed on steel anvil. Both the wheel and anvil have a surface roughness of 1.27 – 1.78 µm (50-70 µin) and a Rockwell C hardness of 55 – 62.

(b) A pendulum system that is capable of being positioned and released at an angle that will impart a predetermined velocity to the sliding anvil. A travel distance of approximately 2.54 cm (1 in) perpendicular to the applied force on the wheel is achieved with this system.

13.5.4.3 *Procedure*

13.5.4.3.1 As a rule substances are tested in the form in which they are received. Wetted substances should be tested with the minimum quantity of wetting agent required for transport. Depending on the physical form, the substances should then be subjected to the following procedures:

(a) Powders are to be tested on the anvil in a monolayer; i.e., the thickness of the granular material, if possible. Place enough granules on the anvil to approximately cover an area 1.27 cm (0.5 in) long by 0.635 cm (0.25 in) wide starting about 0.635 cm (0.25 in) behind the initial contact point of the wheel with the anvil such that the wheel will be in total contact with the sample when lowered onto it.

(b) Solid propellants are tested in the form of thin, uniform slices with a thickness of 0.084 + 0.01 cm (0.033 ± 0.004 in). This thickness is easily obtainable with the use of a microtome cutting tool.

(c) Semisolids will be smoothed with a spatula to a thin layer with uniform thickness approximately 0.015 cm (0.006 in).

With the friction wheel raised, the test substance is placed on the anvil below the wheel such that the wheel will be in total contact with the sample when lowered onto it. The friction wheel is then carefully lowered onto the substance on the anvil and the desired normal force is applied to the wheel [249 N (56 $lb_f$) at 2.44 m/s (8 ft/s) or 445 N (100 $lb_f$) at 1.2 m/s (4 ft/s)]. The pendulum is raised to the desired angle to achieve the appropriate test velocity and released. Observations are made on whether a "reaction" occurs as evidenced by audible report or production of smoke, fire, charring or visible light as observed by human senses. The type of reaction that occurs is documented. The force on the wheel is removed and any excess test substance is cleaned from the area. The wheel is indexed and shifted across the anvil in order to ensure that fresh surfaces are used for each trial.

13.5.4.4 *Maintenance and calibration*

The maximum speed of the anvil should be calibrated to 2.44 m/s (8 ft/s) and 1.2 m/s (4 ft/s). The downward force on the wheel should be verified. The test machine should be periodically cleaned and calibrated according to a schedule based on the amount of usage. At a minimum, the machine should be calibrated on an annual basis.

13.5.4.5 *Test criteria and method of assessing results*

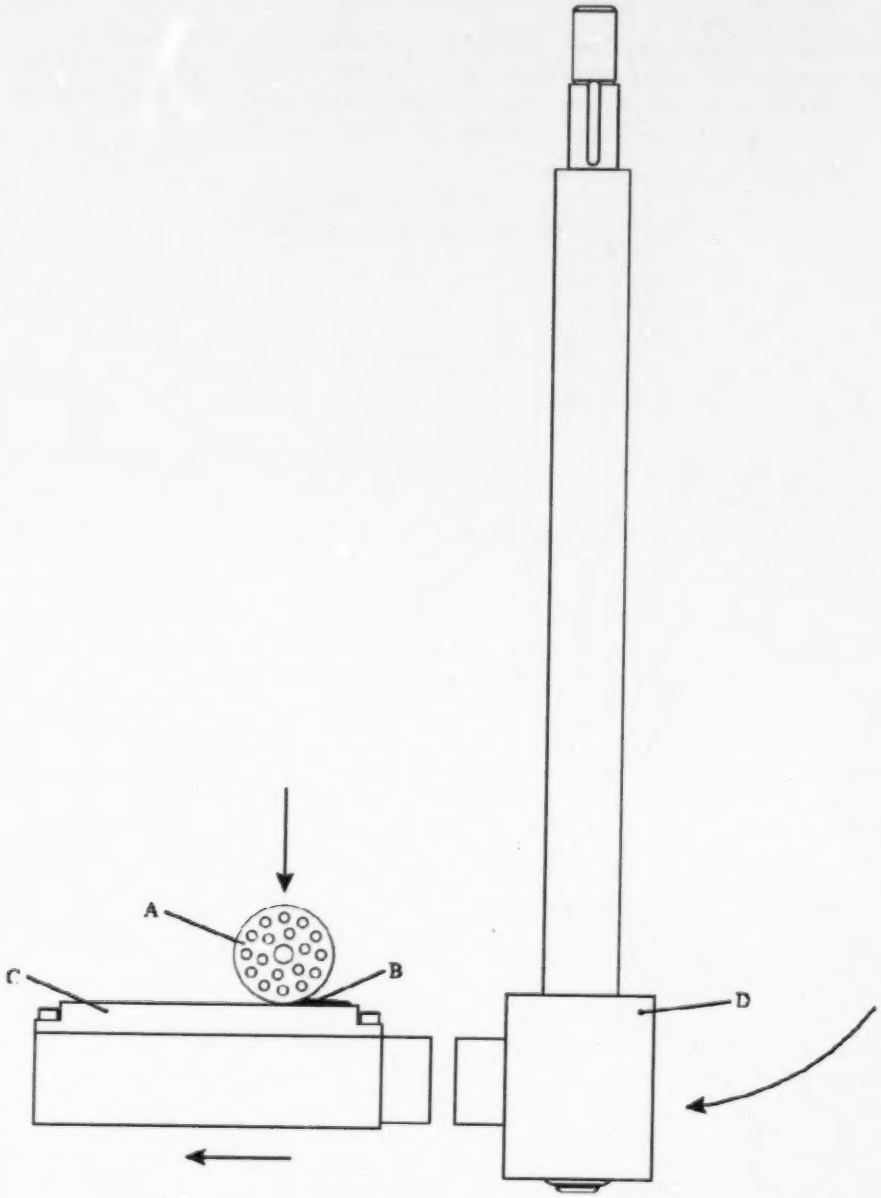
The test result is considered "+" if the lowest friction load at which at least one "go" occurs in six trials is 249 N (56 $lb_f$) at 2.44 m/s (8 ft/s) or 445 N (100 $lb_f$) at 1.2 m/s (4 ft/s) or less and the substance is considered too dangerous for transport in the form in which it was tested. Otherwise, the result is considered "–".

13.5.4.6 *Examples of results*

| Substances[1] | Result |
|---|---|
| RDX (class 5) | – |
| RDX (class 7) | – |
| PBXN-8 | – |
| PBXN-10 | – |
| Aluminum/TNT (80/20 Mixture) | – |
| PETN (dry)[2] | + |

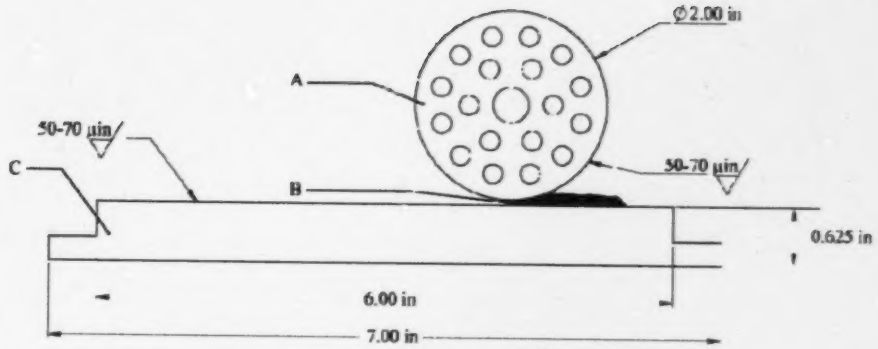
[1] Data acquired at 2.44 m/s, relative humidity of 10-30%, and temperature of 60-75 °F unless noted otherwise.

[2] Data acquired at 2.44 m/s and 1.2 m/s




| | | | |
|---|---|---|---|
| (A) | Non-rotating wheel | (B) | Sample |
| (C) | Anvil | (D) | Pendulum |

**Figure 13.5.4.1: ABL Friction machine**




| | |
|---|---|
| (A) | Non-rotating wheel 5.08 cm (2.0 in) diameter maximum × 3.175 cm (0.125 in) |
| (B) | Sample under test |
| (C) | Anvil 17.78 cm (7.0 in) × 5.715 cm (2.25 in) × 1.588 cm (0.625 in) maximum |

**Figure 13.4.7.2: ABL Friction machine wheel and anvil detail"**